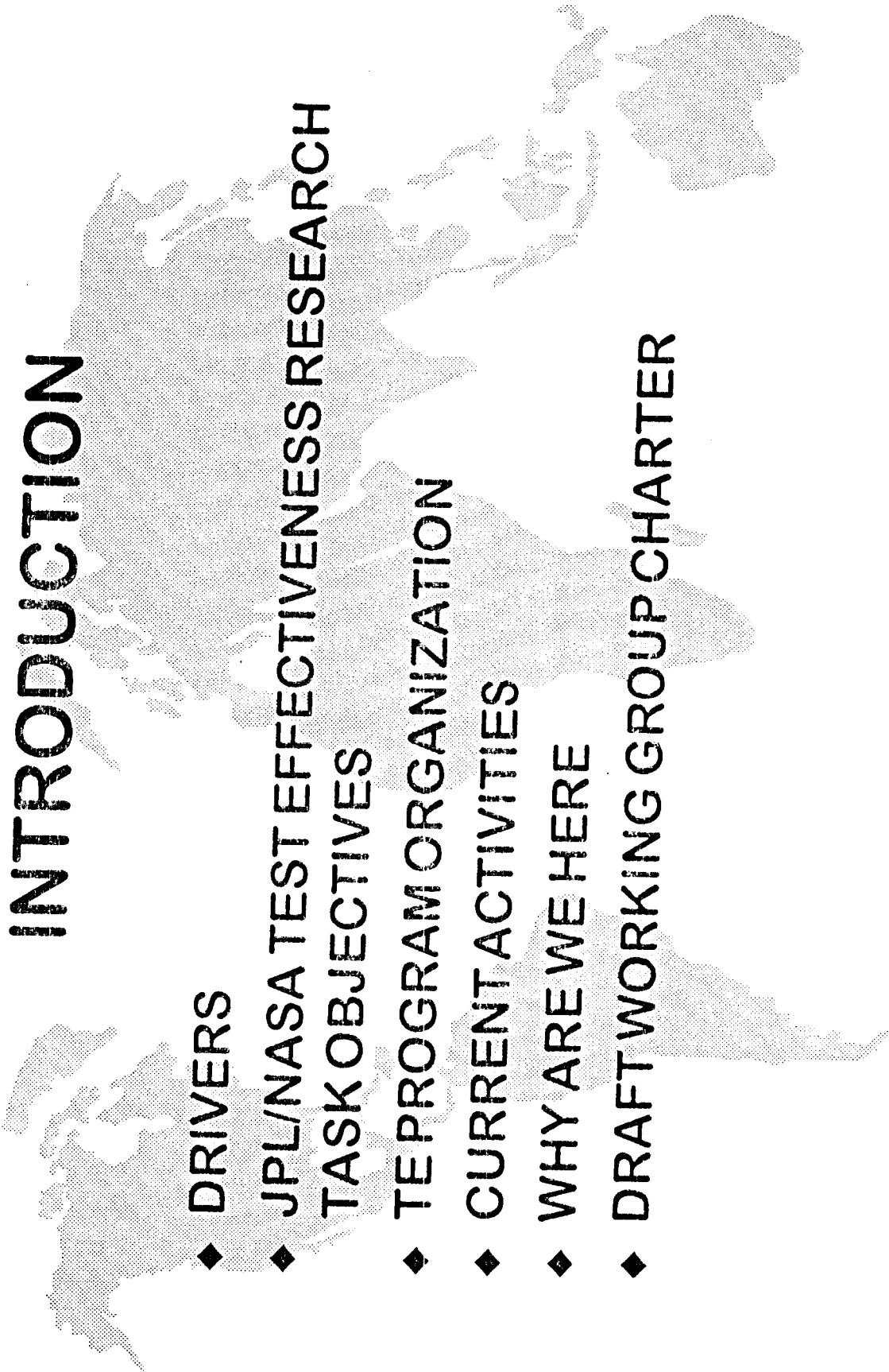


JPL/NASA TEST EFFECTIVENESS WORKSHOP

**MARK GIBBEL/TIM LARSON
& STEVE CORNFORD**

**PASADENA, CALIFORNIA
AUGUST 7 & 8, 1996**



INTRODUCTION

- ◆ DRIVERS
- ◆ JPL/NASA TEST EFFECTIVENESS RESEARCH TASK OBJECTIVES
- ◆ TE PROGRAM ORGANIZATION
- ◆ CURRENT ACTIVITIES
- ◆ WHY ARE WE HERE
- ◆ DRAFT WORKING GROUP CHARTER

TE TASK DRIVERS

- ◆ NASA IS ASKING US TO DO MORE WITH LESS MONEY AND TO DO IT WELL
- ◆ GET NEW TECHNOLOGY INTO PRODUCTS SOONER
- ◆ PROJECT PERSONNEL ARE ASKING US TO HELP THEM IDENTIFY THE LOW VALUE ADDED ASSURANCE TASKS AND THE OVERLY REDUNDANT TASKS
- ◆ ALL WANT PROOF (I.E.. METRICS) OF THE EFFECTIVENESS OF WHAT REMAINS AFTER TRIMAILORING
- ◆ NEED A SYSTEMATIC APPROACH TO ACHIEVE THE ABOVE

DEFINITIONS

– PACTS

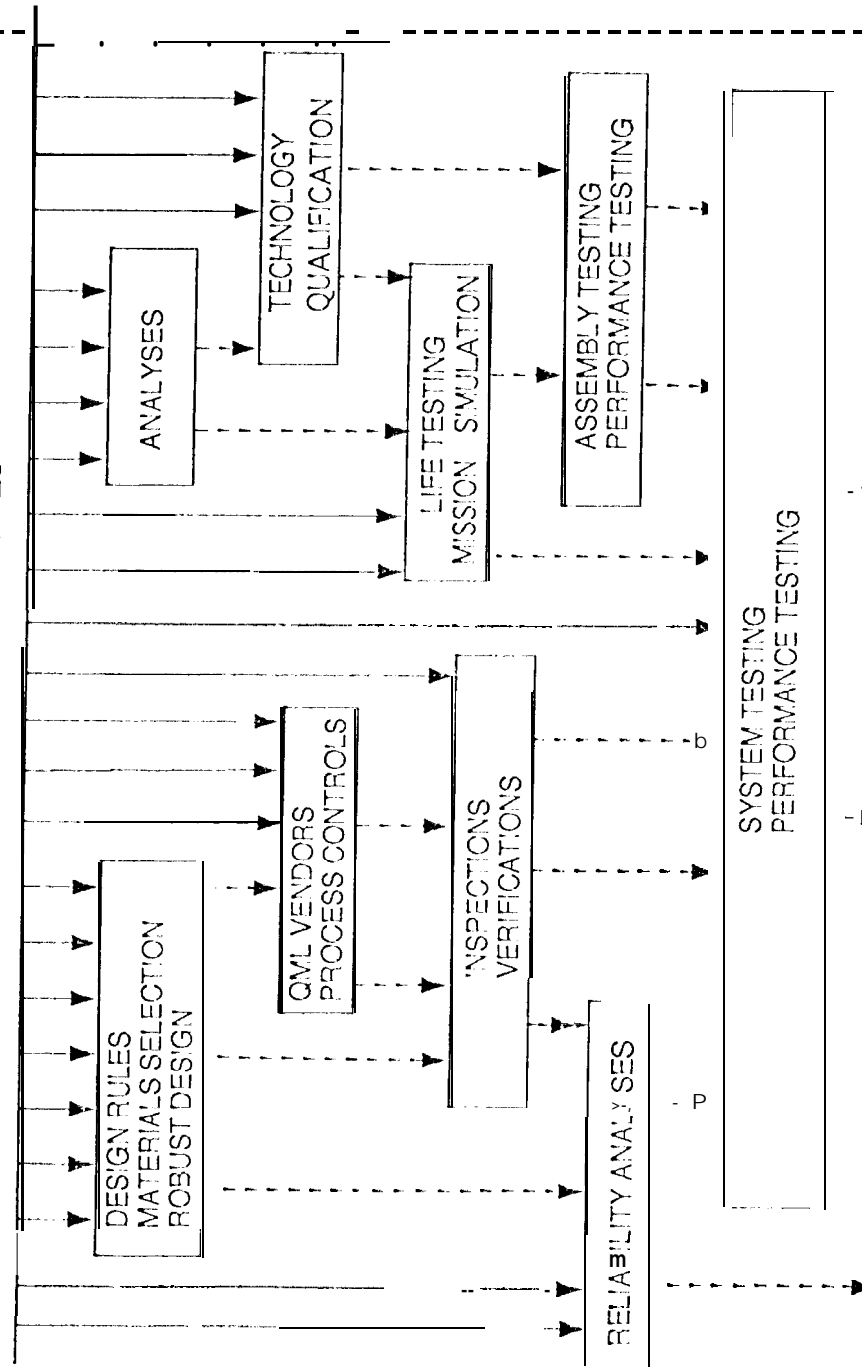
- Preventions (Redundancy, Design Rules, Materials Selection, etc.)
- Analyses (Reliability (FTA, FMECA, WCA), Fatigue, Structural, Performance, SPICE models, etc.)
- process Controls (Inspections, Materials purity, QML vendors, Documentation, etc.)
- Tests (Environmental, Life, Simulations, Performance, etc.)

– FAILURE MODES(FMs)/DEFECTS

- “Hard” - Cracks, Explosions, Open Circuits, etc.
- “Soft” - Resets, Performance Degradations, etc.
- I am using the word failure in its broadest sense: Failure to meet goals/requirements

RAINFALL CHART

HARDWARE FAILURE MODES



MISSION SUCCESS ?

TETAS OBJECTIVES

- ◆ IMPROVE NASA/JPL'S OVERALL EFFECTIVENESS BY ADVANCING THE FIELD OF DEFECT DETECTION AND PREVENTION
- ◆ SHARE EXPERIENCES, KNOWLEDGE AND AVAILABLE DATA IN THE PACT EFFECTIVENESS ARENA
- ◆ LEVERAGE INDUSTRY AND OTHER GOVERNMENT AGENCIES EXPERIENCE, KNOWLEDGE AND AVAILABLE DATA
- ◆ DEVELOPMENT & IMPLEMENT TOOLS & METRICS FOR TECHNICAL & PROGRAMMATIC RISK MANAGEMENT
- ◆ DISSEMINATE RESULTS AND FINDINGS

THE PROGRAM ORGANIZATION

- ◆ ALL ACTIVITIES MAPPED INTO THREE AREAS
 - DATA SOURCES, SYSTEMS
 - METRICS & TOOL DEVELOPMENT & IMPLEMENTATION
 - METHODOLOGY DEVELOPMENT & IMPLEMENTATION

JPL/GSFC TEST EFFECTIVENESS PROGRAM CENTER PROGRAM PLAN THRUSTS

- DATA SOURCES AND SYSTEMS
 - IMPROVED ENVIRONMENTAL TEST AND FLIGHT DATA: Model refinement, Effectiveness data, etc.
 - IMPLEMENTATION OF DATA SYSTEMS: Facilitating data analysis archiving, retrieval and correlation, etc.
 - ADDRESS ISSUES OF QUALIFICATION AND APPLICATION OF DATA: Advanced technologies, unique environments, etc.
- METRICS AND TOOL DEVELOPMENT AND IMPLEMENTATION
 - PROGRAMMATIC METRICS: Cost and schedule impacts, etc.
 - TECHNICAL METRICS: Effectiveness, Technology evaluations, Performance, etc.
- METHODOLOGY DEVELOPMENT AND IMPLEMENTATION
 - VALIDATION AND TESTING APPROACHES FOR: Advanced Technologies, Unique Environments, etc.
 - INNOVATIVE AND SYNERGISTIC METHODS USING: Consolidation of assurance activities, combined environments, etc.

WHAT ARE WE DOING?

- DATA GATHERING
 - COMMON THREADS WORKSHOP (COMING)
 - TEST EFFECTIVENESS WORKING GROUP (STARTED)
 - FLIGHT PERFORMANCE WORKING GROUP (COMING)
 - SLAM FORCE DATA
 - NCMS ESS2000 (INDUSTRIAL SCREENING EFFECTIVENESS)
 - THERMAL CYCLE/DWELL WORKSHOP
 - SSED (DoD "P/FR PLUS" DATA BASE) SSED=SPACE SYSTEMS ENGINEERING DATABASE
 - INDUSTRY BEST PRACTICE SURVEYS
- TOOL DEVELOPMENT
 - PACT KNOWLEDGE BASE
 - FM KNOWLEDGE BASE
 - PROBLEM LOG DEVELOPMENT (P/FR FRONT END)
- METHODOLOGY DEVELOPMENT
 - POFF BASED TESTING (UTILIZE A "ROOT CAUSE" VIEWPOINT TO DEVELOP AND IMPLEMENT SPECIFIC TESTS)
 - EOL SIMULATION (VOLTAGE, TEMPERATURE AND FREQUENCY CAN SIMULATE AGING AND RADIATION)
 - DDP (UTILIZES THE MATRIX-BASED ACEQ ENGINE TO WEIGHT RELATIVE EFFECTIVENESS OF PACTS ON FAILURE MODES WHICH ARE OF THE MOST CONCERN)
 - COLD ELECTRONICS (WHAT KEEPS US FROM OPERATING OUR ELECTRONICS COLD?)
 - SYNERGISTIC TESTING (MORE LATER)
- IMPLEMENTATION
 - "NMP TECHNOLOGY VALIDATION STATUS" - WORKING WITH BARBARA WILSON
 - ACEQ ON NMP (STARTED)
 - ACEQ ON MDL (COMING)
 - FLIGHT DEVELOPMENT REENGINEERING (STARTED)

WHY ARE WE HERE

- ◆ TO FOSTER COMMUNICATION, EXCHANGE/SHARING TECHNICAL INFORMATION AND COLLABORATION
- ◆ PROMOTE UNDERSTANDING OF THE INTERRELATIONSHIPS BETWEEN VARIOUS ACTIVITIES SUCH AS DESIGN, ANALYSIS & MANUFACTURING (EQUIPMENT CAPABILITIES & PROCESS CONTROLS)
- ◆ ADVANCE OUR COLLECTIVE TECHNICAL KNOWLEDGE IN THE FIELD OF DEFECT DETECTION & PREVENTION

Test Effectiveness Working Group

Draft Charter August 7 & 8, 1996

GOALS: The goal of this working group is improve the overall competitiveness of our respective organization's by advancing the field of defect detection and prevention. It is intended that this goal will be achieved by a combination of:

- 1) By fostering communication, collaboration and the exchanging/sharing of technical information,
- 2) Promotion of a greater understanding of the interrelationships between design, analysis, manufacturing (equipment capabilities, processes and controls),
- 3) Advancement of technical education in these areas,
- 4) Working harmoniously with other professional organizations (such as IEEE and IES).

OBJECTIVES: Specific objectives of the working group are to support the innovation, development, evaluation and implementation of test methods, metrics and tools based on failure engineering/physics and/or root cause evaluations. Data sources systems and tools shall be developed and implemented that: 1) provide improved preventions, controls, analyses and tests (PACT) & field failure data collection, 2) facilitates data analysis, archiving, retrieval, failure physics and/or root cause evaluations and 3) enable new and existing technology suitability evaluations to be performed. Metrics developed and implemented shall address the efficiency and efficacy of a PACT as well as any PACT-induced damage. Test methods and strategies will be formulated for improving, combining and/or optimizing existing options among PACT's.

It is intended that the above objectives will be achieved through a combination of:

- 1) Sharing of experience/knowledge between working group members,
- 2) Identifying industry practices and metrics in use and developing and implementing needed metrics,
- 3) Leveraging the experience, knowledge and available data of industry and the government in the PACT effectiveness arena,
- 4) Combining available data and information to identify patterns and trends, and
- 5) Providing a mechanism to identify opportunities to collaborate with industry and/or dissemination of PACT effectiveness results and findings.

BENEFITS: The intended benefit of the working group is to improve the overall competitiveness of our organizations by:

- 1) implement improvement, tradeoffs and eliminate low value-added activities based on identified trends and technical data,
- 2) Increase the perception of being a value added activity by our respective organizations,
- 3) Providing cost effective education/information dissemination to the working level within organizations,
- 4) improving the quality and quantity of available data by developing and implementing tools for measuring the efficiency and efficacy of all of the processes involved in making reliable products, and
- 5) Providing an opportunity for leveraging, and or collaboration.

CUSTOMERS: We consider our customers to be our respective organizations, their internal projects, project personnel, our supplier partners, each other organization's and the users of our products.

NCMS ESS 2000 PROJECT

PRESENTED BY

Mark Gibbel

Authors alphabetical ordered:

Marvin Bellamy TI

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John I-less Storage Tek

Tracy Pattok NCMS

Andrew Quintero Aerospace

R Silver ATT



ESS 2000

Advancing the State-of-the-Art in Environmental Stress Screening

^ genda

- ESS 2000 vision statement
- ESS definition
- Drivers
- Objectives
- Participants
- Project description
- Technologies description
- Deliverables
- Summary

ESS 2000 Vision Statement

Enhance the knowledge necessary to implement cost-effective, leading-edge ESS technologies and procedures in order to increase U.S. electronics industry competitiveness



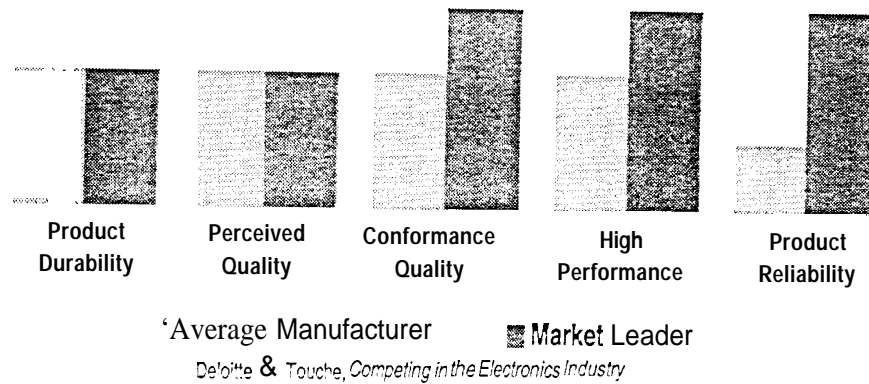
ESS Definition

Environmental Stress Screening- (ESS) of electronic hardware is a manufacturing process performed to identify and segregate those items (part, module, subassembly, box, or system) defined as defective. Appropriate environmental stresses are chosen to force latent defects that would otherwise fail in the field into observable failures in the factory. These stresses may be unrelated to mission, use, or qualification levels.

Project Drivers

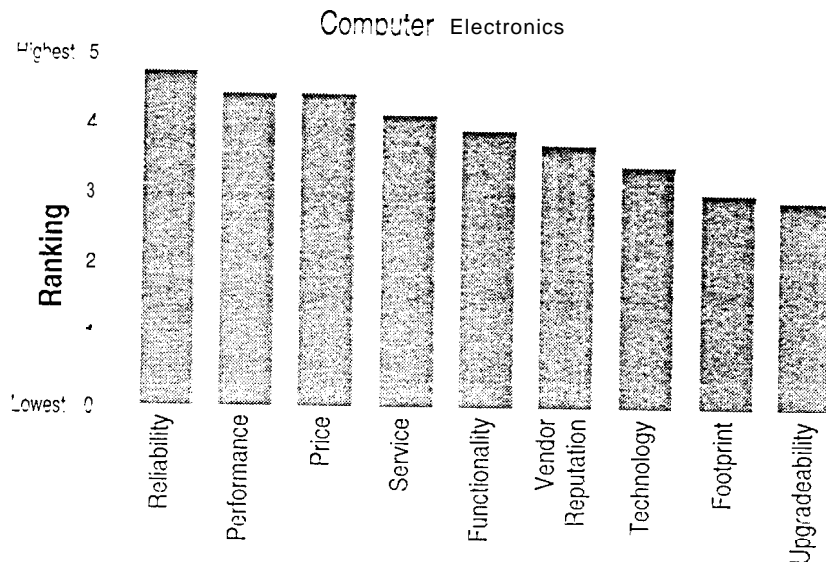
- Market competitiveness
- Product quality/reliability
- Time to market
- Significant \$ and time devoted to ESS development and processes
- Tool for process improvement and new product process development

Gaining Competitive Advantage Through Product Quality



Project Driver: Product Quality/ Reliability

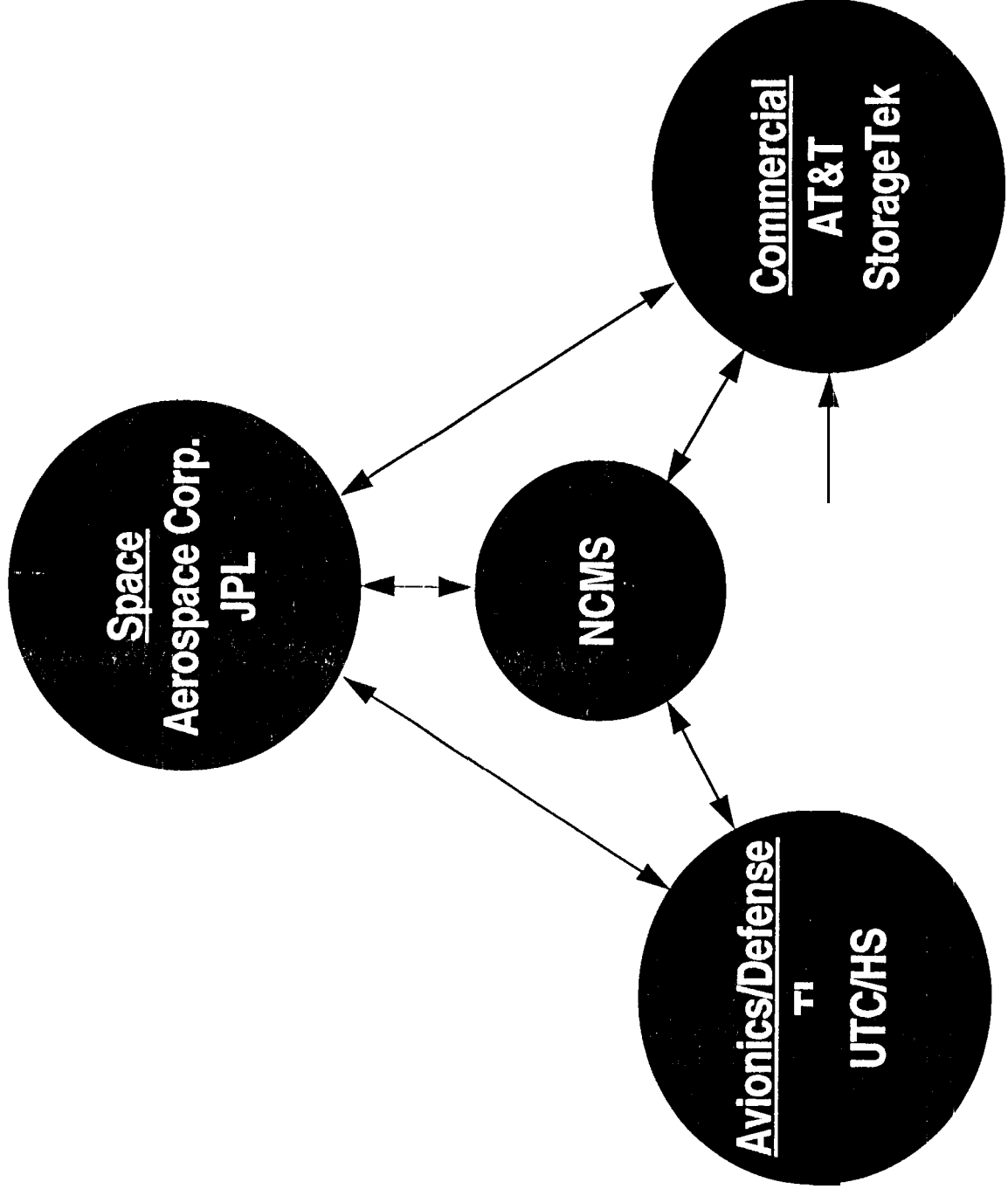
Gartner Customer Requirements Survey



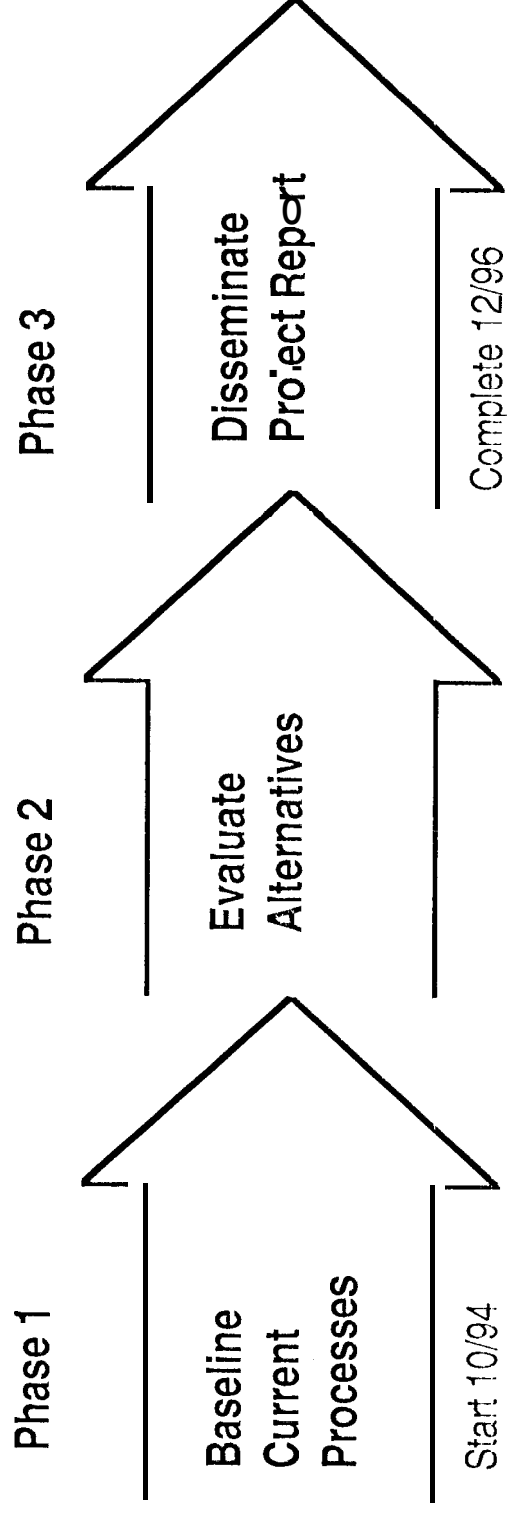
Project Objectives

- Establish and compare baseline processes
 - “cost
 - Cycle time
 - Failure mechanisms
- Utilize resources of multiple companies
- Develop common database to collect process and failure data
- Use value added screening effectiveness (VASE) matrix to evaluate and enhance leading-edge ES S technologies
- Disseminate results to industry

Project Participants



ESS 2000 Project Description



- Preliminary work
- Establish database
- Collect data
- Safety of screening test
- Develop VASE
- ESS software joint life test
- Secure hardware
- Perform alternative ESS
- Perform design of experiments
- Collect & evaluate field reliability data
- Generate final report
- Transfer technology

Project Technologies Description

- Key Screening Stresses
- Pneumatic HALT/HASS
- Electrodynamics HALT/HASS
- Liquid Environmental Stress Screening (LESS)
- Value Added Screening Effectiveness (VASE) Matrix

Key Screening Stresses

- Temperature ramp rates and levels
- Dwell times
- Vibration levels/types
- Voltage margining
- Frequency margining
- Combinational stresses
- Stress order/level

Pneumatic **HALT/HASS**

- Highly accelerated ESS employs combined stresses that exceed those experienced in traditional ESS
- Typical equipment capability:
 - Simultaneous application of stresses
 - Multi-axis vibration
 - 20 to 60°C/min ramp rates
 - Power/frequency/voltage cycling
 - Functional testing

Electrodynamics **HALT/HASS**

- Uses combined stresses described previously but employs electrodynamics vibration in lieu of pneumatic vibration
- Typical equipment capability:
 - Simultaneous application of stresses
 - Single-axis vibration
 - User-tailorable autospectrum
 - 20 to 60°C/min ramp rates
 - Power/frequency/voltage cycling
 - Functional testing

Liquid Environmental Stress Screening (LESS)

- Applies environmental stresses to a product through the use of an inert, non-conductive fluid
- o Typical equipment capability:
 - Liquid-to-liquid shock (-20 to +80°C)
 - Simultaneous voltage margining
 - 500 to 1000°C/min ramp rates
 - Functional testing

Value Added Screening Effectiveness (VASE) Matrix

- A tool that ranks the effectiveness of ESS processes based upon:
 - Product characterization data
 - Process tracking data
 - Anomaly investigation data
 - Field failure data

VASE (continued)

Failure Mode	ICT	ESS #1	ESS #2	ESS #3	ED ESS	LESS
Solder #1			.4			
Solder #2				.4	.9	
Lifted lead		.9				
Wire bond				.7		

ESS/Test Technology

Failure Mode	Assembly				
	SP	RF	Wave	SMT	DYCO
Solder #1	x		x	-	
Solder #2				x	
Lifted lead	x	x			
Wire bond					

Manufacturing Process/ Technology

Tool Box

Screen Printing

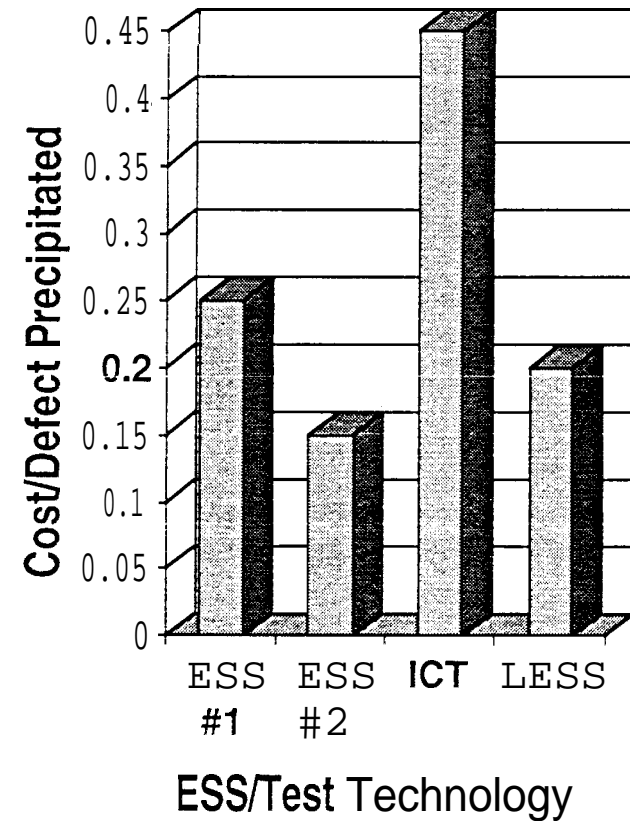
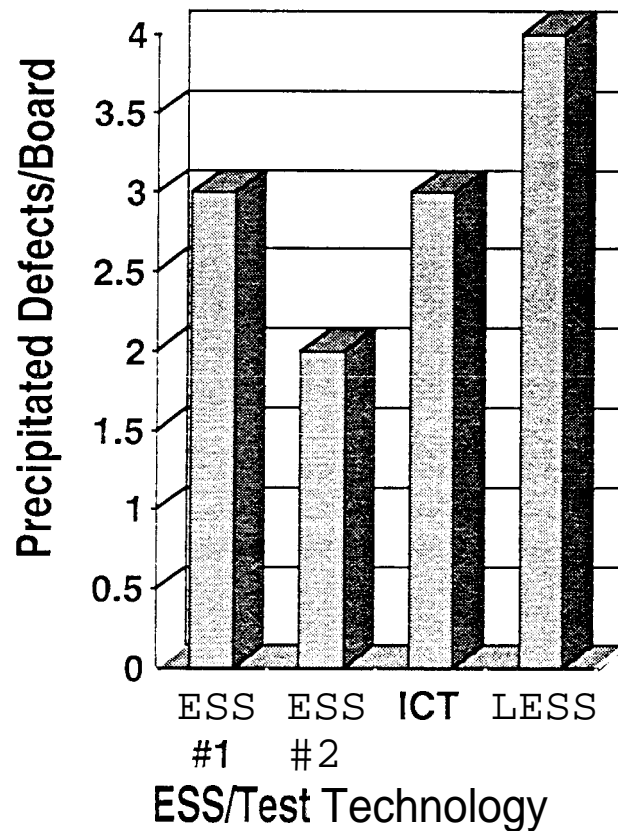
Volume

Stencil

Humidity

Solder Temperature

VASE (continued)



Project Deliverables

- NCMS proprietary ESS 2000 database
- Objective evaluation of ESS technologies
- Value added screening effectiveness matrix (optimization tool)
- Final report

Summary

- Project aims to enhance the knowledge necessary to implement cost-effective, leading-edge ESS technologies and procedures
- Compare effectiveness of baseline ESS processes to alternatives
- Utilize multiple companies to evaluate leading-edge ESS technologies
 - Pneumatic HASS
 - L&SS
 - Electrodynamic HASS
- Disseminate project report

THERMAL TESTING STUDY

Steven Cornford

Jet Propulsion Laboratory
California Institute of Technology

Paul Plumb

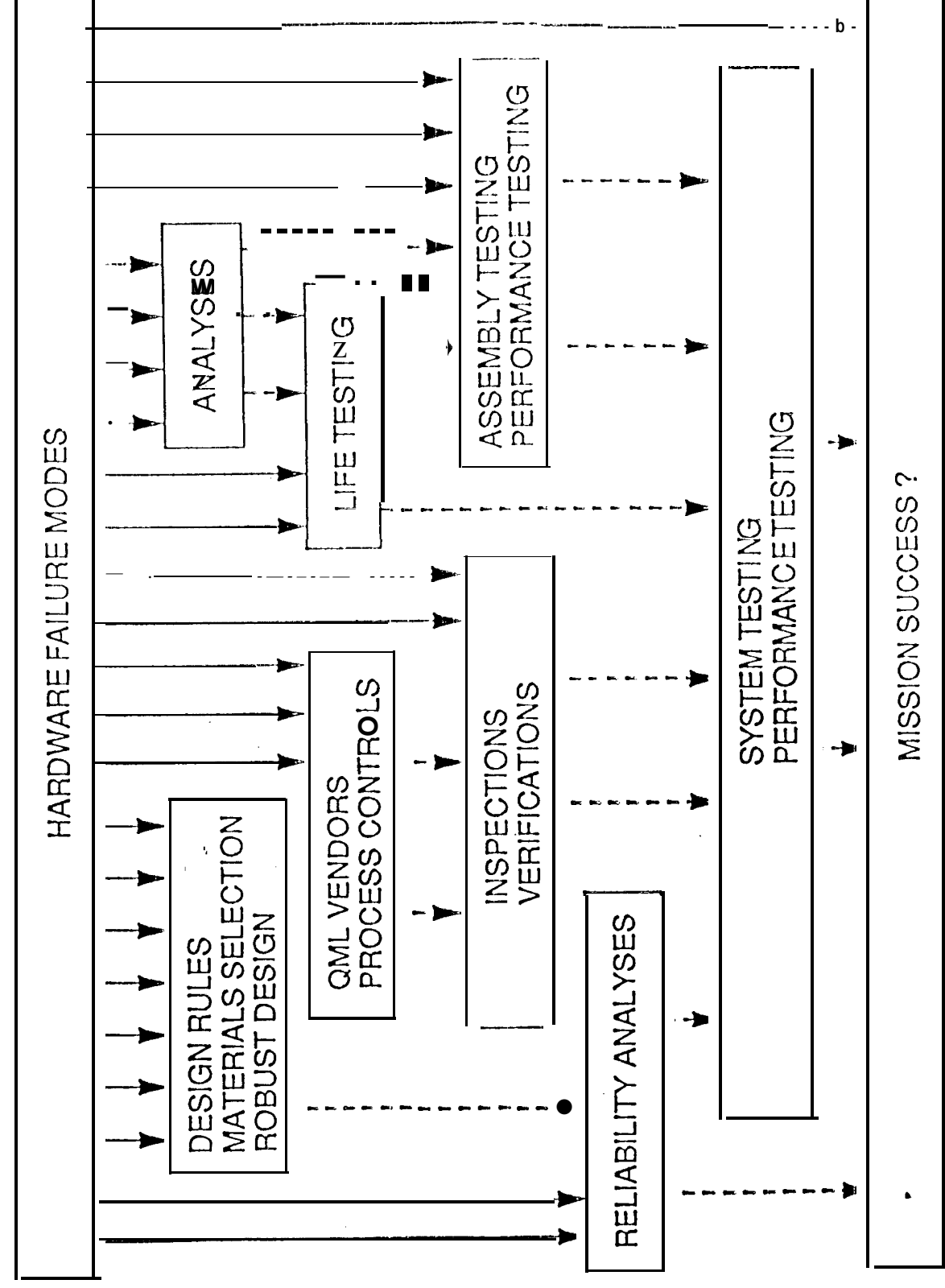
Lockheed Missles and Space Company, Inc.

THERMAL CYCLING -- THERMAL DWELL

- Issue: Should Thermal Cycling continue to be used for flight hardware verification?
- Thermal cycling' has been proposed as standard test technique for protoflight testing
- Recently, tests and analyses suggest:
 - » multiple cycles may not be necessary for adequate design qualification and workmanship verification
 - » cycling degrades the intrinsic lifetime and reliability of the hardware.
 - » increased dwell durations/levels are more important than cycles for effective qualification and verification.
 - » fast and slow ramp rates may exercise different failure modes
- **Solution: Do thermal dwell testing as a standard (at most two cycles with a fast and a slow ramp rate).****

* (10 cycles @ max predict -k/- 10C (NASA), 39.5 cycles @ -5410 71C + mission cycles (Mil-Std-1540C)

.* (Some special circumstances may require thermal cycling also)



THERMAL TESTING STUDY

- Investigation into the effectiveness of thermal cycle and thermal dwell testing
- Sponsored by NASA Code QT
- Resulted in release of the Thermal Testing Study Report, JPL D-1 1958
- Presented at the 15th Aerospace Testing Seminar
 - » Great interest
- Presented at the Thermal Control Workshop @ Aerospace Corporation
 - » Great interest
 - » Aligned with presentation on commercial practices
 - » Hughes has found “most failures occur in the first few cycles”

REASONS FOR THERMAL TESTING

- **DESIGN VERIFICATION**

- » FUNCTIONAL PERFORMANCE

- DESIGN ROBUSTNESS, BEGINNING/END OF LIFE, HYSTERESIS, MATERIAL COMPATIBILITY, ETC.

- » THERMAL PERFORMANCE MARGIN

- VERIFICATION OF ANALYSES ASSUMPTIONS, VERIFICATION OF TEMPERATURE RANGES, MARGIN DEMONSTRATION

- **WORKMANSHIP SCREENING**

- » BURN-IN FAILURES, THERMAL CHANGE FAILURES, FATIGUE FAILURES

- **ACCELERATED AGING**

- » INTO THE USEFUL LIFE REGIME

ACCOMPLISHING THE OBJECTIVES

**LOOK AT TESTING PARAMETERS REQUIRED FOR
SCREENING/EXERCISING VARIOUS FAILURE MODES**

- **REQUIRES HOT/COLD LEVELS ONLY**

- » BURN-IN FAILURES, ACCELERATED AGING, FUNCTIONAL PERFORMANCE, BOL/EOL SIMULATION, ASSUMPTION VERIFICATION, TEMPERATURE RISE VERIFICATION, MATERIAL COMPAT BILITY

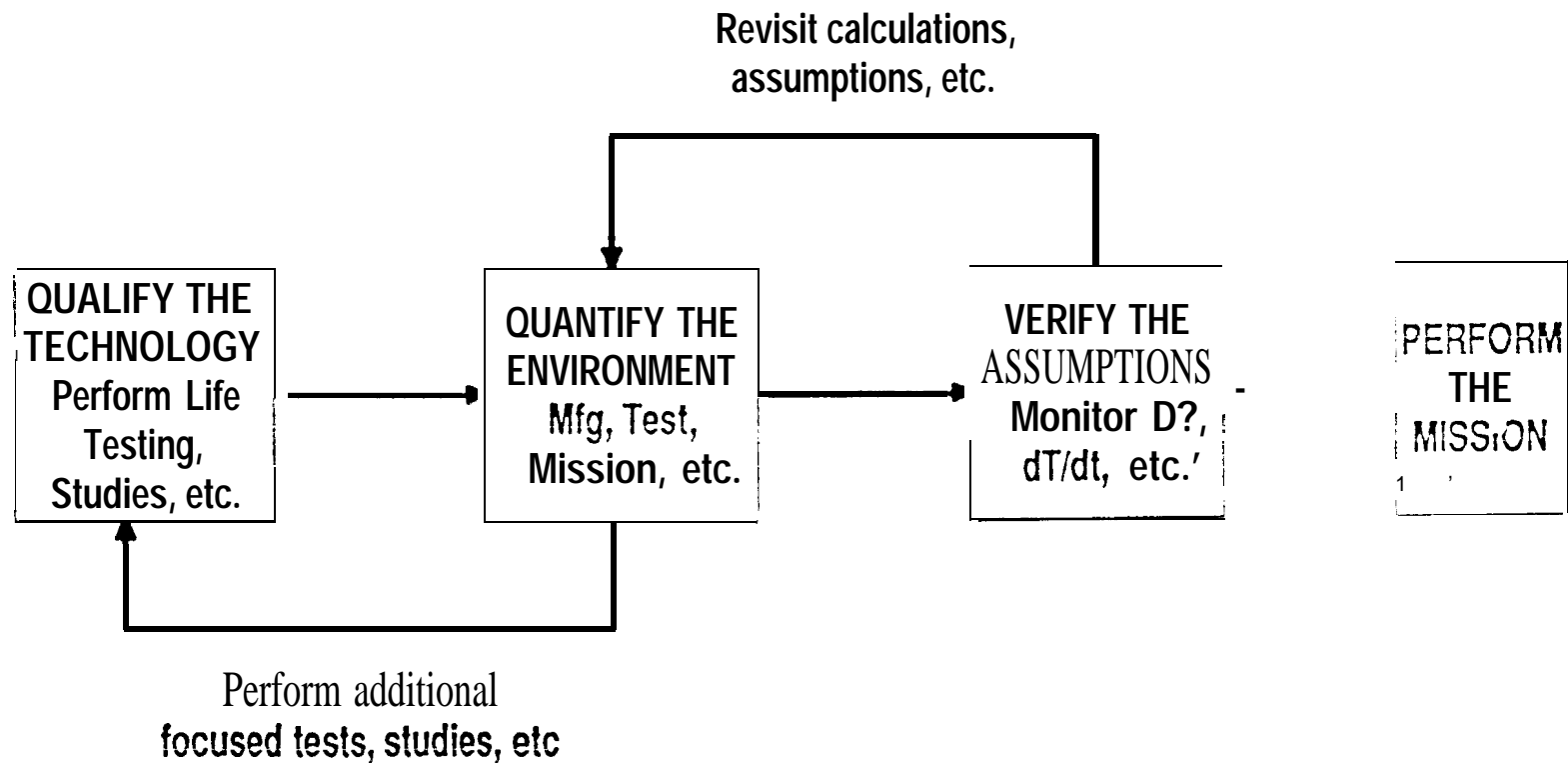
- **REQUIRES >1 CYCLE**

- » FATIGUE FAILURES, HYSTERESIS EFFECTS

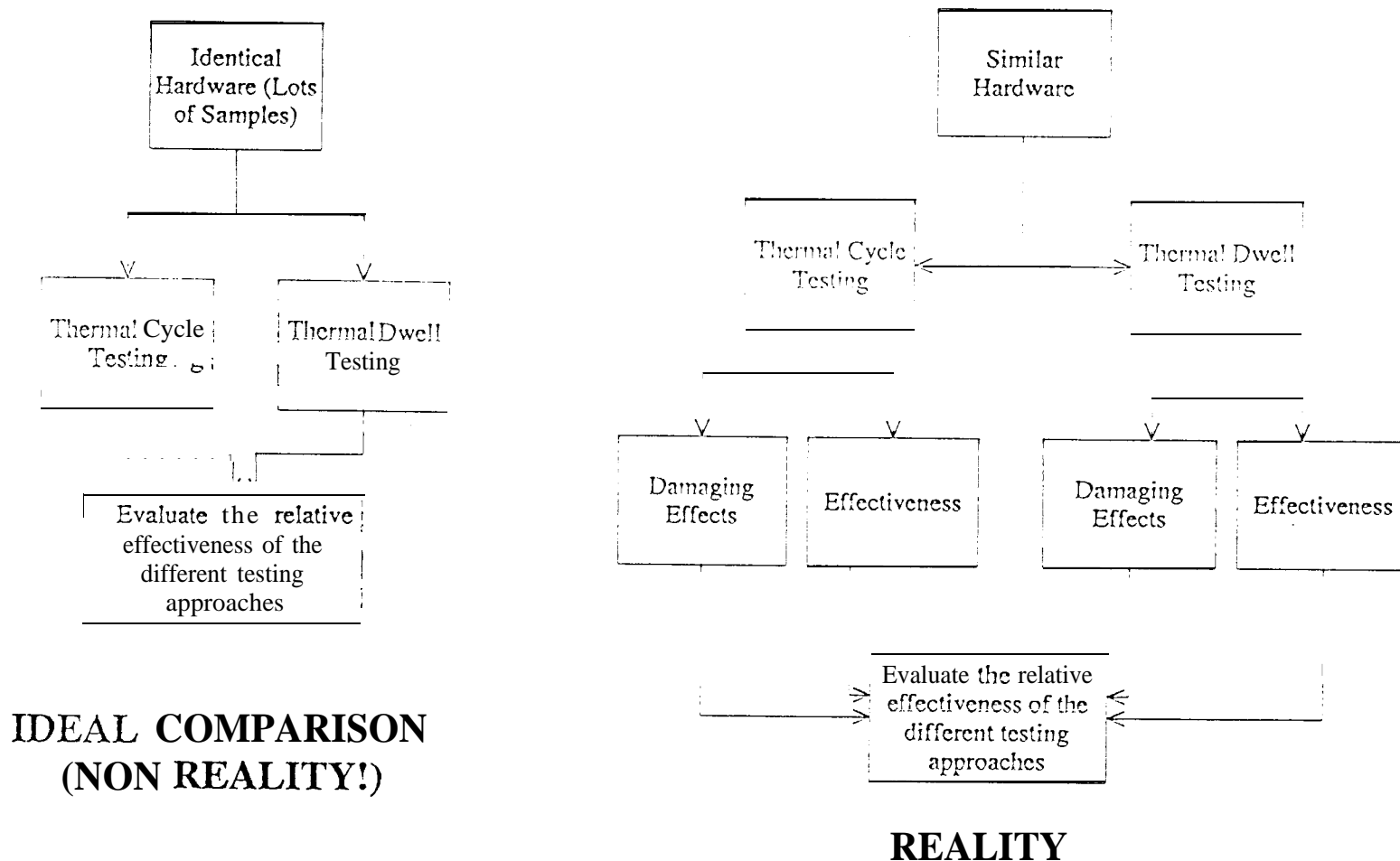
- **REQUIRES MANY CYCLES**

- » FATIGUE LIFE QUALIFICATION

QUALIFYING FATIGUE SENSITIVE HARDWARE



RELATIVE TEST EFFECTIVENESS STUDY APPROACH



EFFECTIVENESS DATA

DWELL TESTING

- TEST EFFECTIVENESS STUDIES
 - » COLD/HOT TEMPERATURE
 - TIME DEPENDENT AND IN DEPENDENT
 - » FLIGHT FAILURE CORRELATIONS
 - » VACUUM, ASSEMBLY/SYSTEM LEVEL
- FLIGHT DATA

CYCLE TESTING

- LITERATURE SEARCH FOR CURRENT DATA
- UNIVERSAL CURVE
 - » BIMODAL POPULATIONS
 - » EQUIVALENCE TO BURN-IN
- HISTORICAL BASIS
- EXCEPTIONS

LITERATURE DATA

“””””

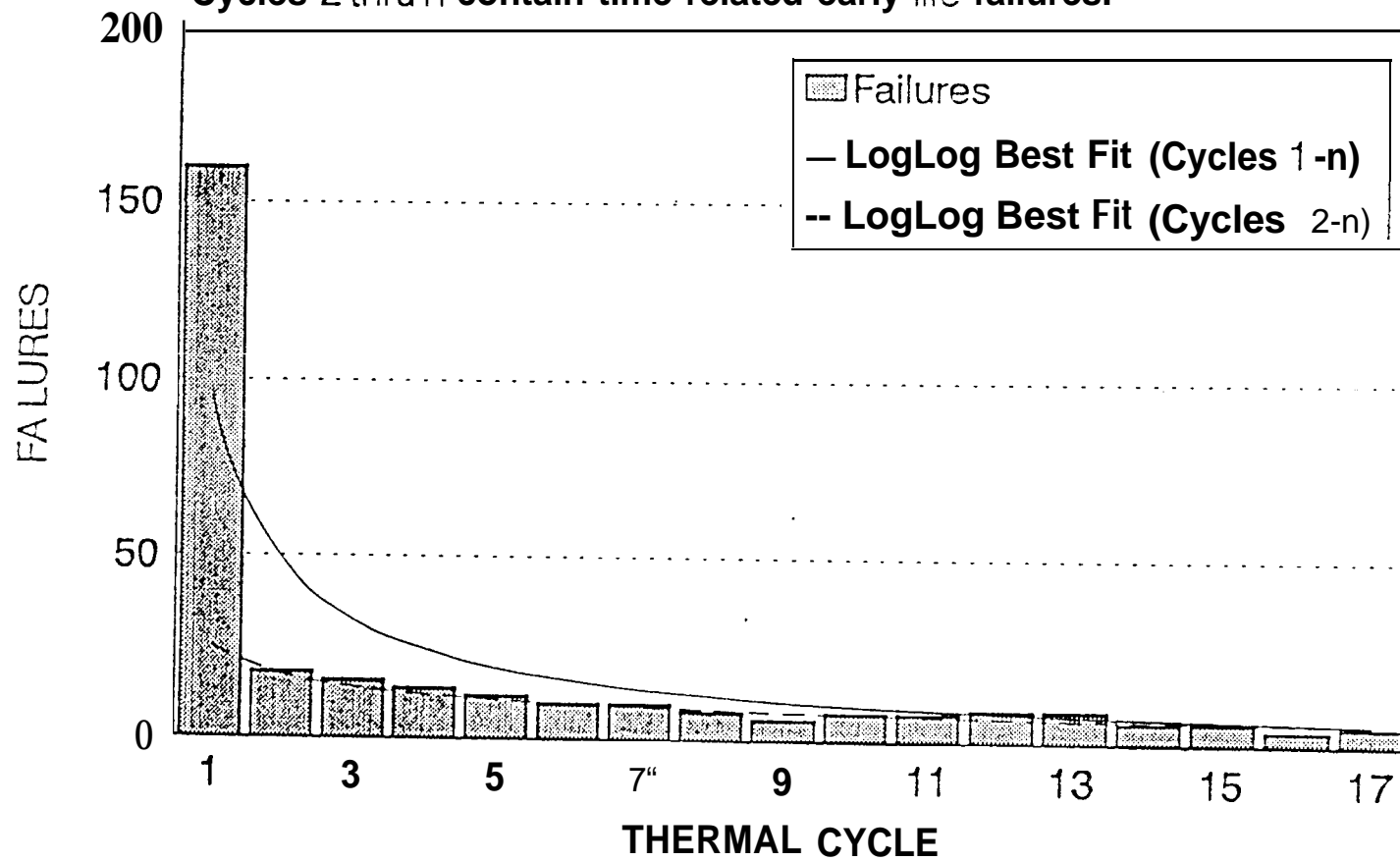
- 1200 IBM Low Voltage Power Supplies
- 48 LMSC Spacecraft Boxes
- 313 LMSC Satellite Boxes
 - 216 Milstar Satellite Boxes
- 63 Navy Standard 80 MB Disk Drives

- 17,180 AT&T Commercial Circuit Boards
 - » FAST AND SLOW RAMP RATES
- IES Data
 - » COMBINED VIBRATION AND THERMAL CYCLE TESTING
 - » LABELED (IN 1984) AS “THERMAL CYCLES”

Universal Thermal Cycle Best Fit Curves

Cycle 1 has separate population of thermal related failures.

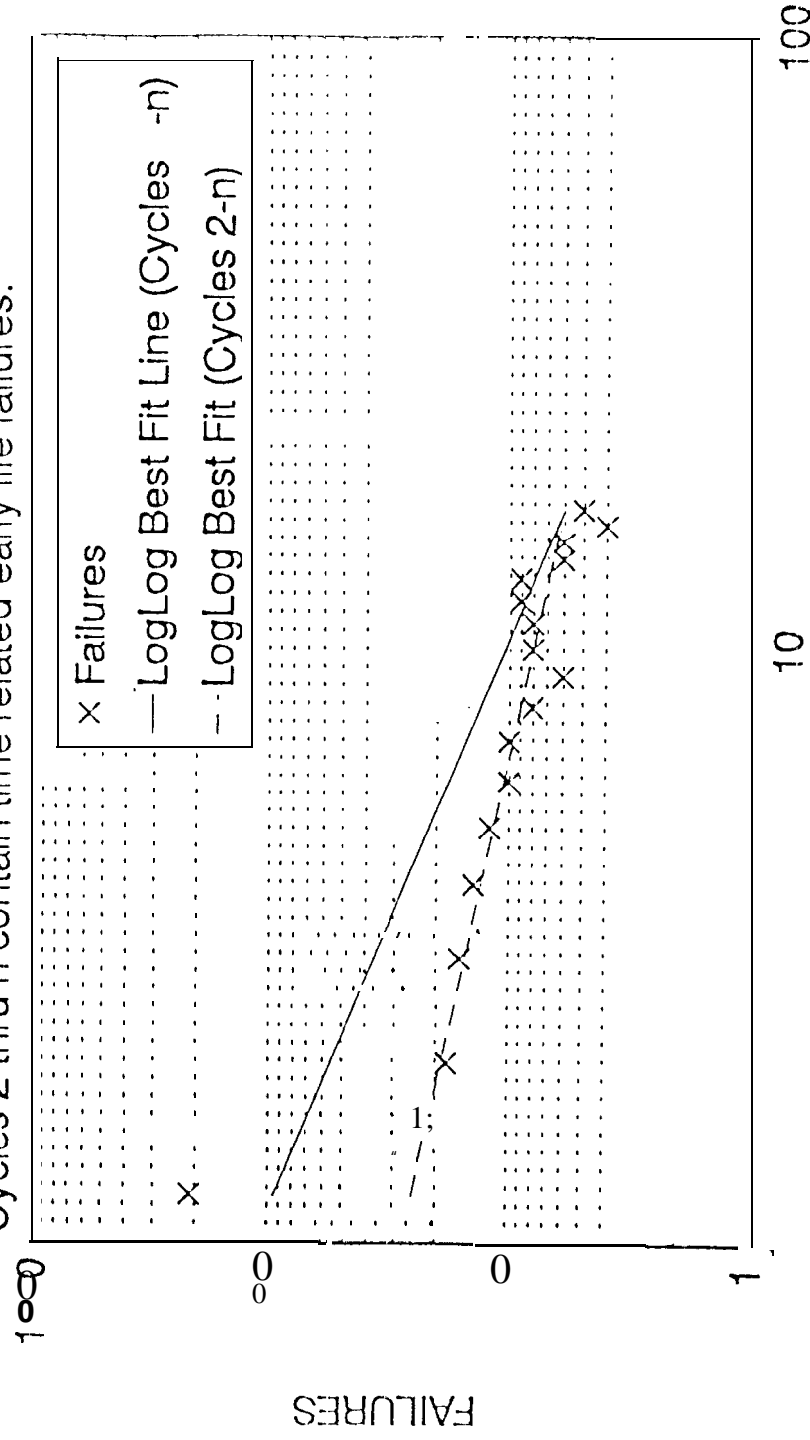
Cycles 2 thru n contain time related early life failures.



Electronic/Electro Mechanical Data

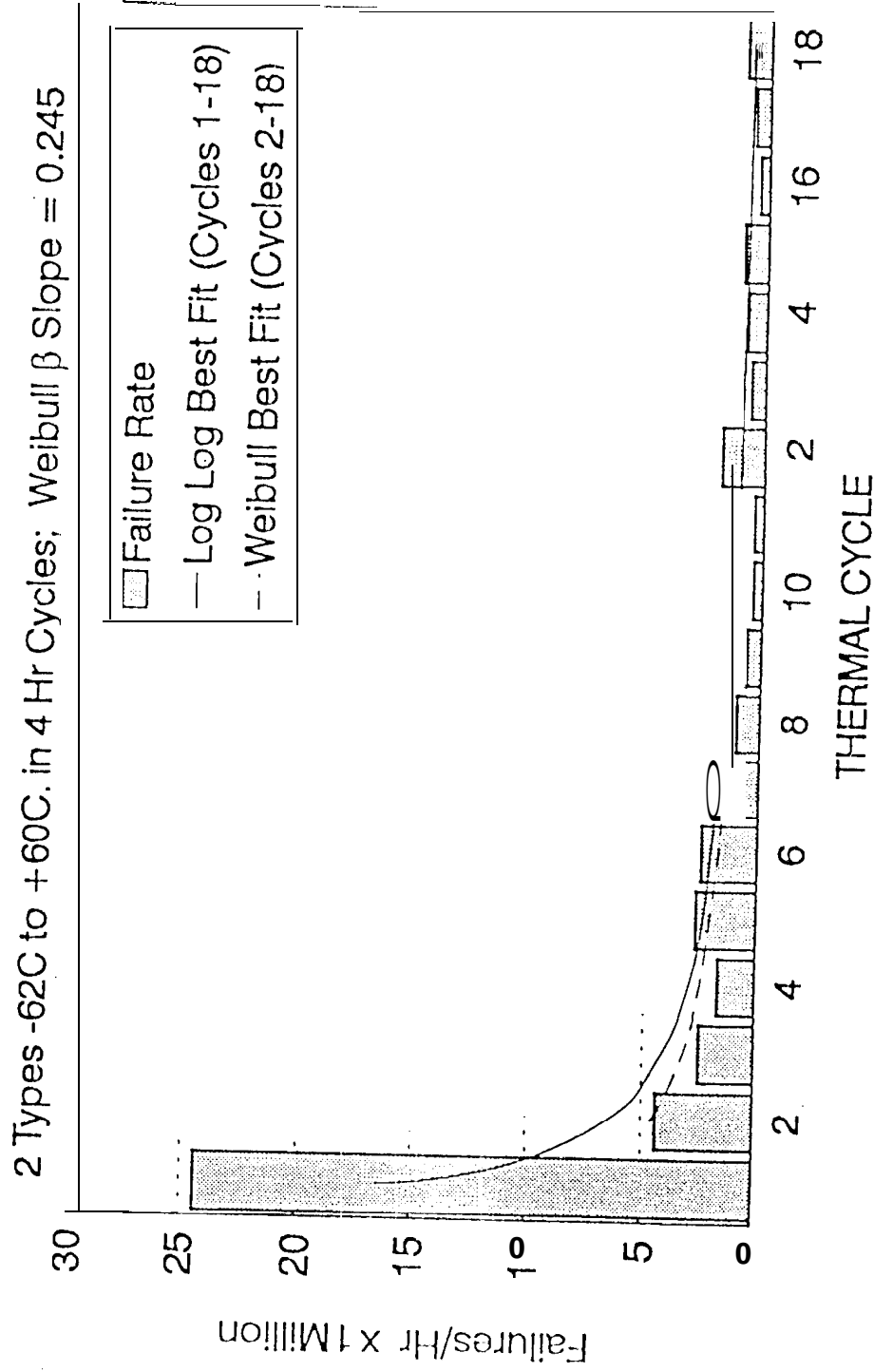
Universal Thermal Cycle Log Plot

Cycle 1 has separate population of thermal related failures.
Cycles 2 thru n contain time related early life failures.



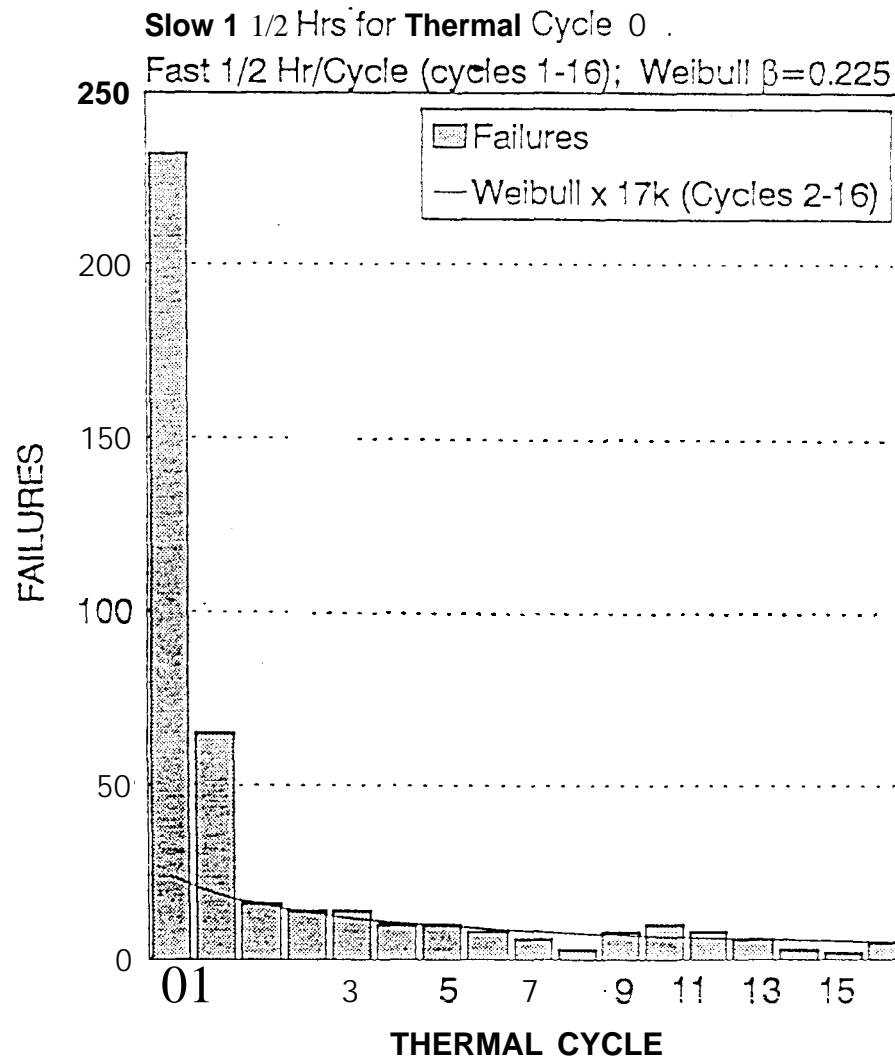
Electronic/Electro Mechanical Data

Figure 4.5-1
 1200 IBM Low Voltage Power Supplies
 (Thermal Cycle Plot)

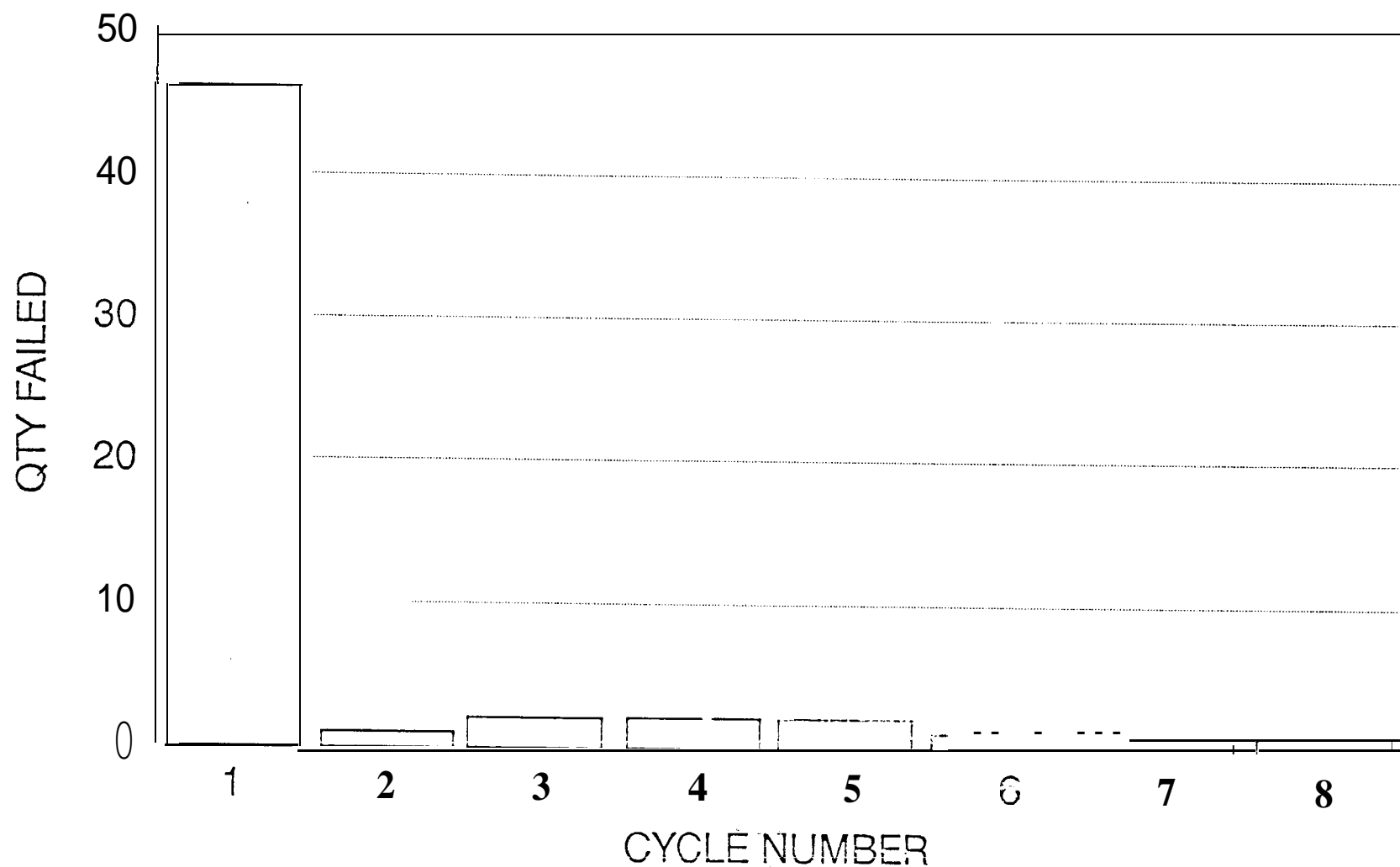


1200 IBM Mil Spec PS, 977

"17,1 80 AT&T Commercial Ckt Bds Failure Plot (Thermal Cycled from -20 to +70C)



COMPONENT THERMAL VACUUM CYCLE TEST (31 3 Satellite Boxes Tested 1979- 1992)



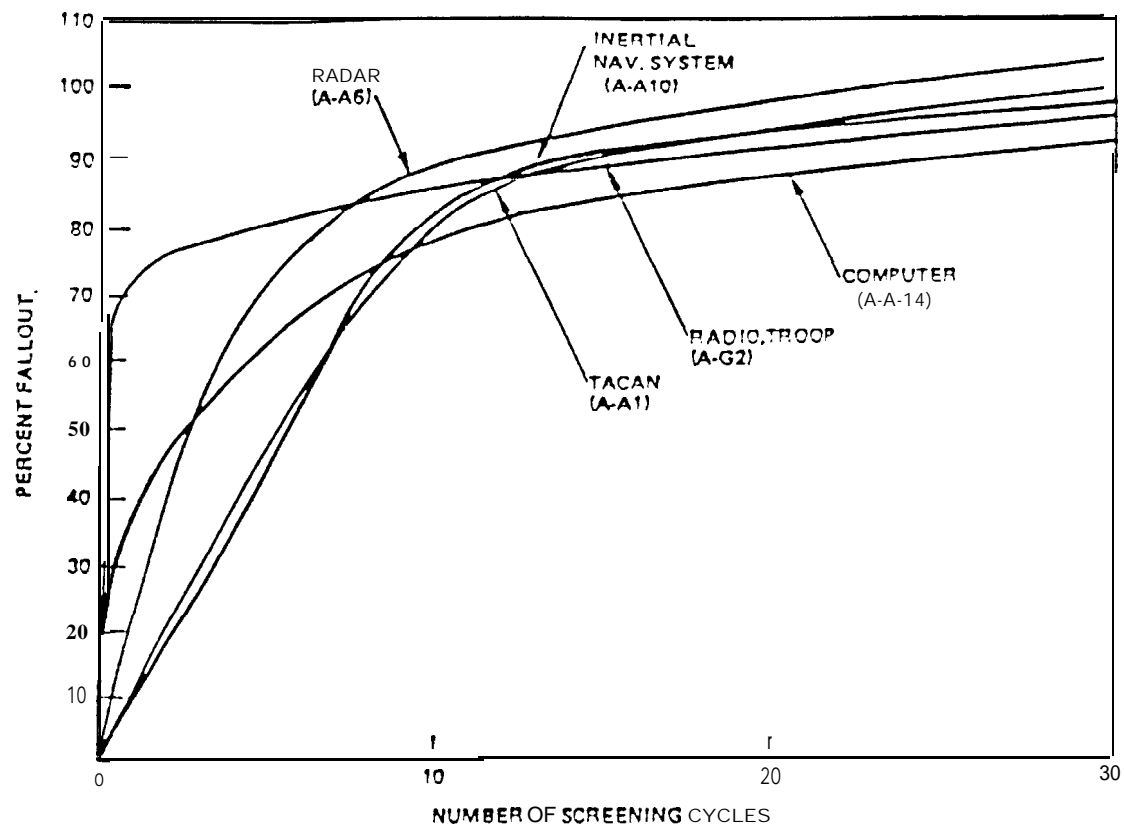
Lockheed Data on One Program

Figure B

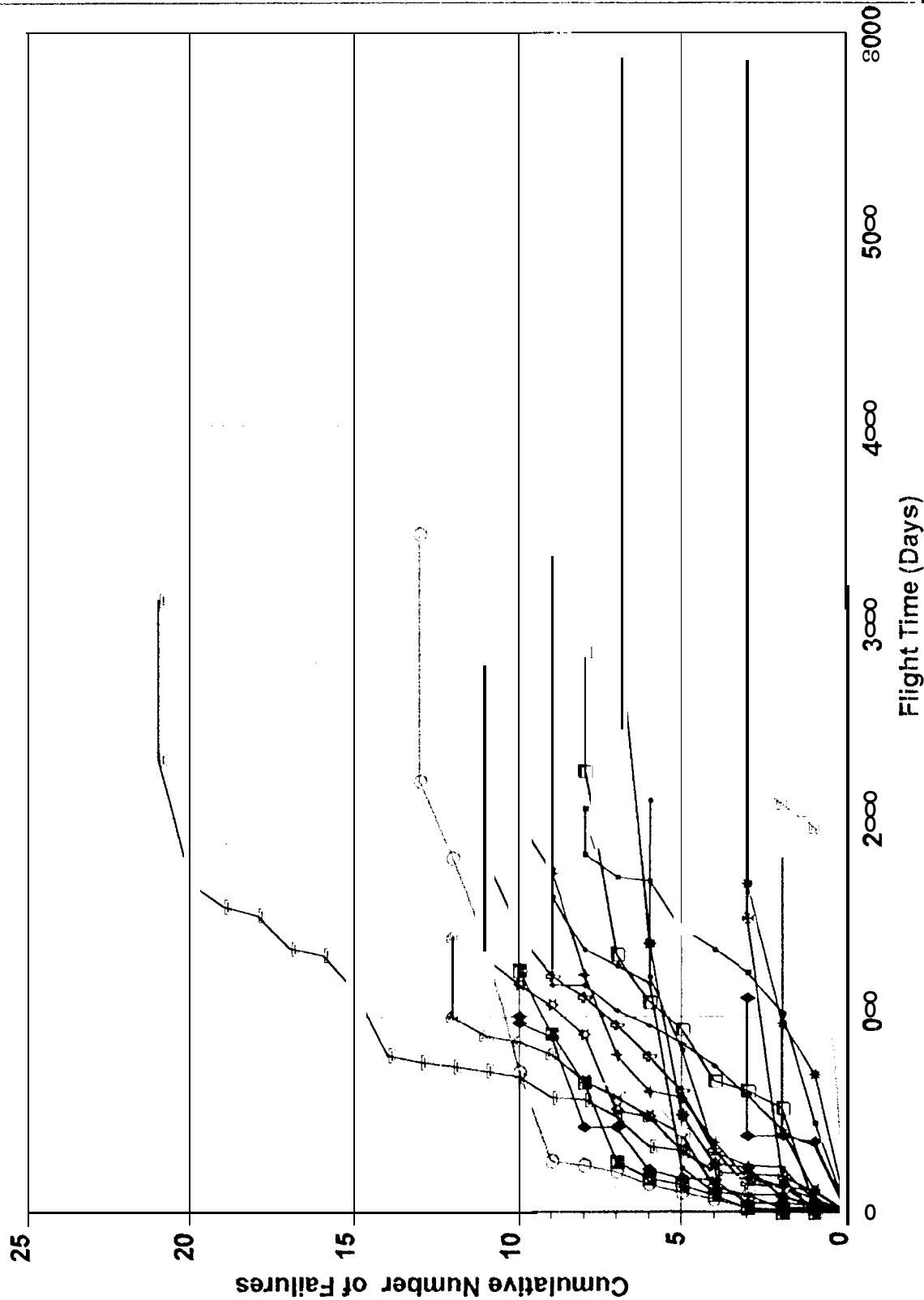
1981 IES ESSEH SCREENING CYCLE GRAPH

Combined Vibration & Thermal Cycles From 1981 IES ESSEH (Mislabeled as Thermal Cycles in 1984 ESSEH Guideline)

Radio, Troop (A-G2) is a Thermal Cycle test. Others contain Sine Vibration in each cycle



Cumulative Number of Failures on Orbiter and Interplanetary Spacecraft as Function of Flight Time



Note: The last point on each horizontal line is the end of observation period and the point before the last is the data point for the last observed failure.

EQUIVALENCE OF CYCLES 2-N TO ROOM TEMP BURN-IN

- PRIAM 638 DISK DRIVE
 - » LARGE POPULATION OF DISK DRIVES
 - » 25C BURN-IN AND CYCLING DATA
 - RATE OF CHANGE OF FAILURES IDENTICAL FOR CYCLES 2-N
 - » ARRHENIUS EQUATIONS PREDICTS EQUIVALENCE FOR 0.3 eV

- IF THE FAILURE MECHANISMS ARE DIFFERENT, HOW CAN IDENTICAL HARDWARE FAIL AT THE SAME RATE UNDER DIFFERENT TESTS?

SUMMARY

- RE-ASSESS EXISTING THERMAL TESTING PROGRAMS
 - » CONSIDER RATIONALE FOR THERMAL TESTING
 - » DETERMINE THE “TALL POLE” FAILURE MECHANISMS
 - » SELECT SCREEN/TEST BASED ON RELATIVE EFFECTIVENESS, DAMAGING EFFECTS, COST
- **CONCLUSIONS**
 - » PERFORM THERMAL DWELL INSTEAD OF THERMAL CYCLING **AS** A STANDARD*
 - » CYCLE TO AT MOST TWO (FAST AND SLOW RATE)
 - » INCREASE LEVELS AND DURATIONS OF DWELL
 - » PERFORM SEPARATE FATIGUE LIFE QUALIFICATION
 - » ELIMINATE POWEREDOFF SCREENING

* (Some special circumstances may require thermal cycling also)

End of Life Simulation
(Test Effectiveness Program)

Michael A. Gross

**Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109**

Environmental Test & Stress Screening Effectiveness Workshop
August 7-8, 1996

Objectives of End-of-Life-Simulation

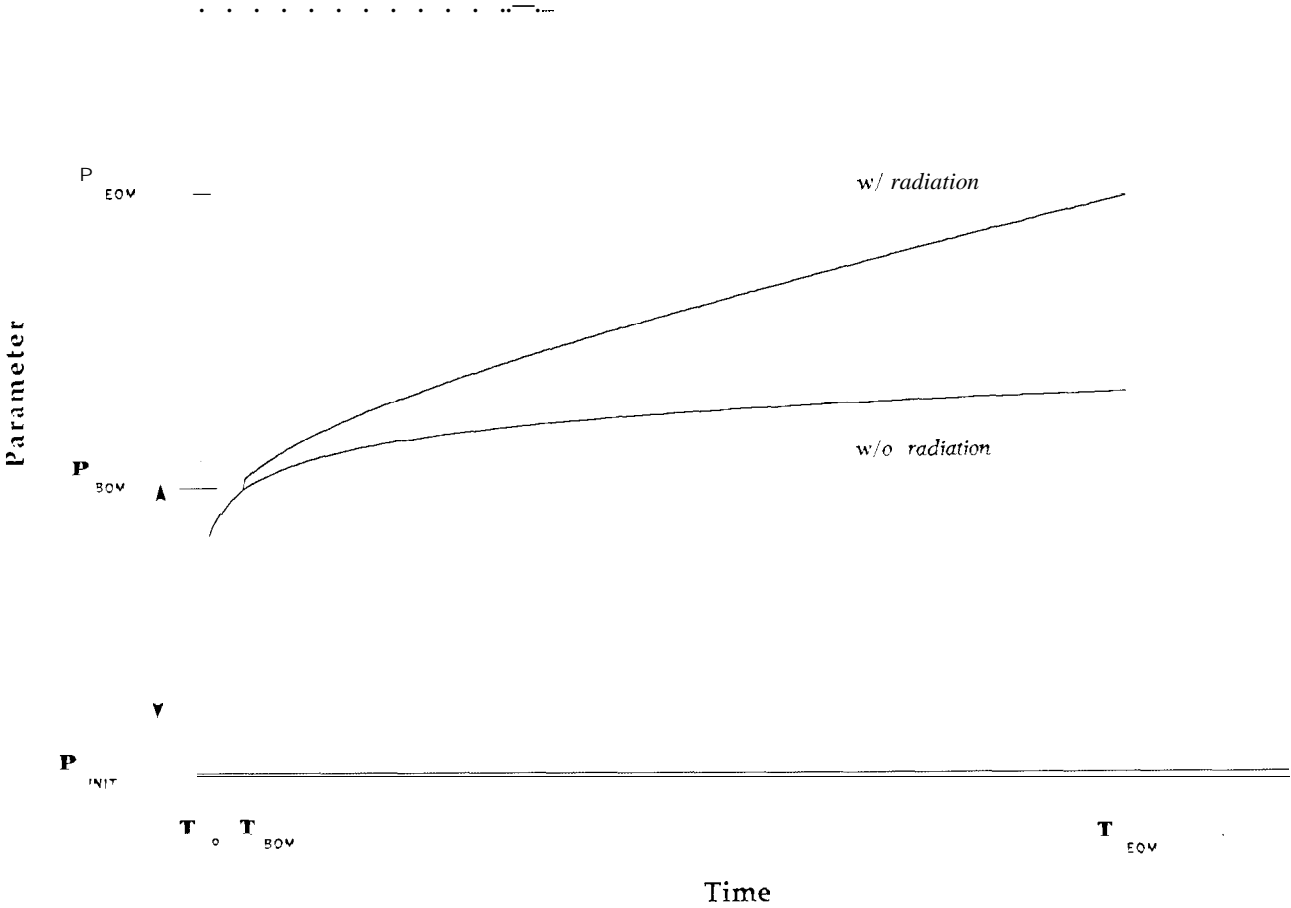
- Develop & Validate an approach to testing which demonstrates mission performance throughout the mission life cycle
- Correlate relations between existing Worst Case Analysis(WCA) and Voltage Temperature Margin Testing (VTMT)
- Analyze VTMT effectiveness
- Develop EOL Simulation Guidelines

Purpose of End-Of-Life Simulation

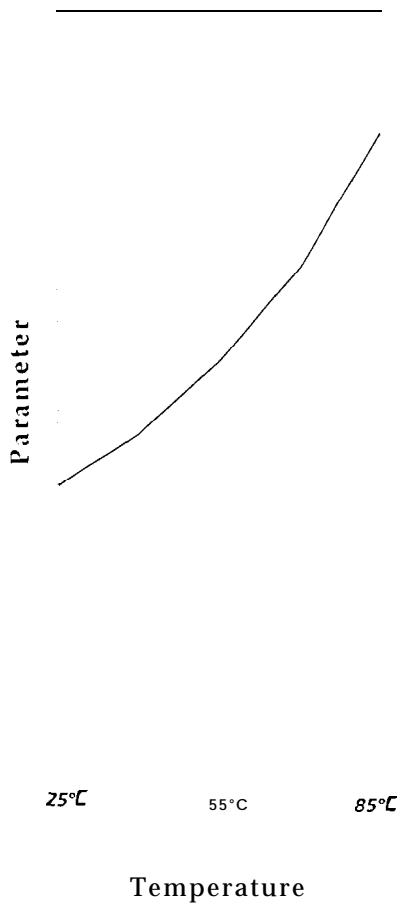
- Investigations show that voltage, temperature and frequency margins are actually simulating performance after aging
- Validation by test and/or measurement end-of-life circuit functionality

END OF MISSION ELECTRICAL DESIGN VERIFICATION

Electrical Parameter Variation vs. Mission Timeline



Parameter Value vs. Temperature



Driving Force Behind End-of-Life Simulation

- Faster, Better and Cheaper Methods to ensure mission performance
Quantitative Verification of design performance and robustness

Benefits of End-of-Life Simulation

- Cost savings to projects:
 - Currently a WAC and VTMT costs between 20-70k\$
 - Combination can save between 30-40k\$
- A concurrent process is achieved:

Testing and Analysis is performed simultaneously from the design stage to the verification and acceptance stage

Measurable Products of End-of-Life Simulation

- Standard guidelines for implementing EOL Simulation
- Catalog of typical circuit blocks used in NASA applications
 - E.g.. course filter of the power systems and synch oscillator
- Part Critical Parameter Database



Synergistic Testing

(Test Effectiveness Program)

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Environmental Test & Stress Screening Effectiveness Workshop
August 7-8, 1996

JPL

Synergistic Testing

- **Goal:**

Minimize existing tests and analyses, while maintaining the desired reliability and effectiveness, for Faster Better Cheaper missions.

- . **Objectives:**

- 1. Look for overlaps and duplications in existing tests and analyses.**
- 2. Combine them into a minimum set.**
- 3. Look for synergism between tests and analyses (effectiveness of the combined is greater than the sum of the individual ones).**

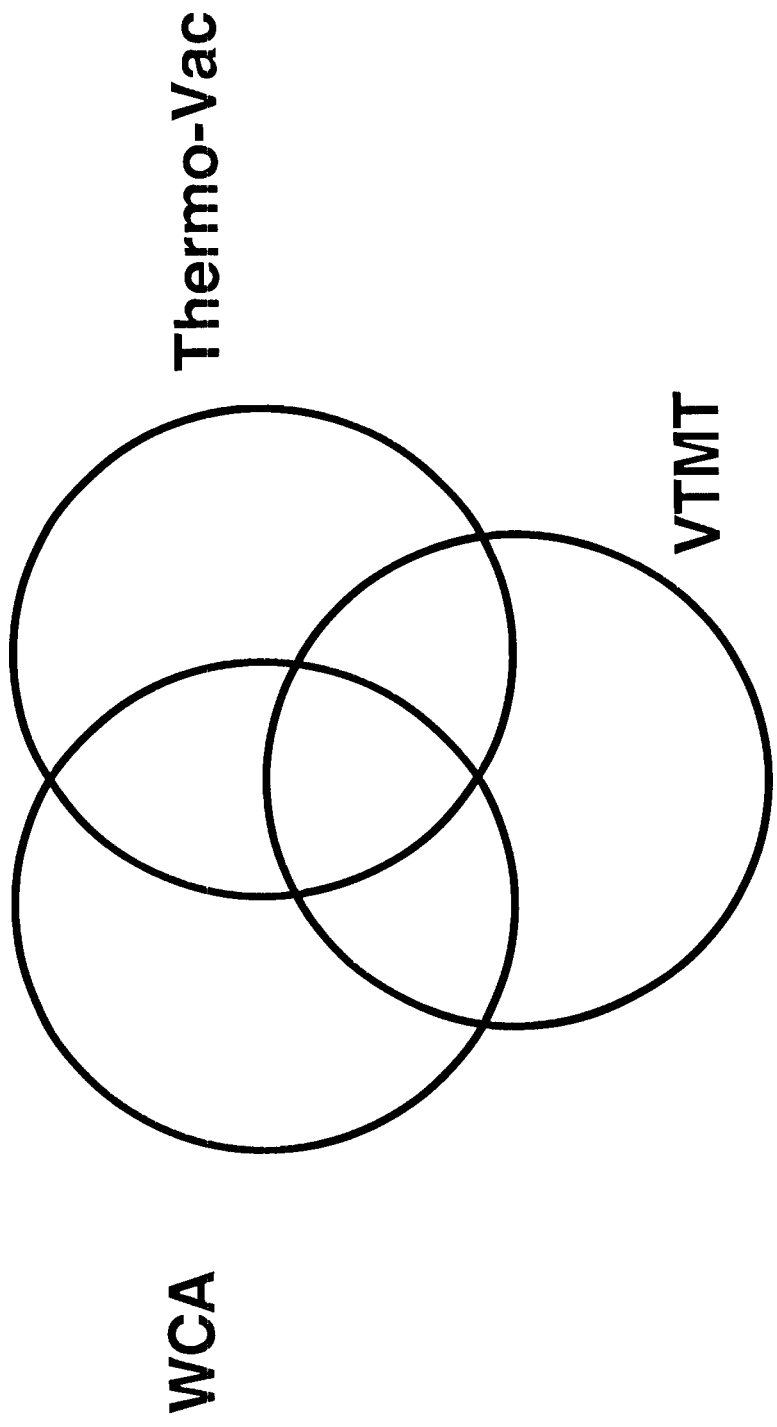
- . **Examples:**

- 1. Vibration + hot or cold.**
- 2. Thermal + vacuum.**
- 3. Combine WCA & VTMT with thermal-vat.**



Present Focus in Synergistic Testing

Combine WCA, VTMT and thermal/vacuum into a simplified VTfMT in vacuum.





Objectives of WCA, Thermal/Vat, and VTMT

- **Objective of WCA: Evaluate performance within the worst case scenario.**
 - . **Validate performance under worst case voltage, input signal, and part variation (caused by aging, radiation, environmental stresses).**
- **Objective of thermal/vacuum: Demonstrate reliability and robustness under flight-like conditions.**
 - . **Validate performance under thermal (hot and cold) and vacuum (in addition to ambient) environments.**
- **Objective of VTMT: Demonstrate robustness of design by simulating end-of-life conditions and functionally test for worst case operational parameters.**
 - . **Subject hardware to environmental and operational conditions (voltage, input signal, frequency) that exceed their nominal requirements.**



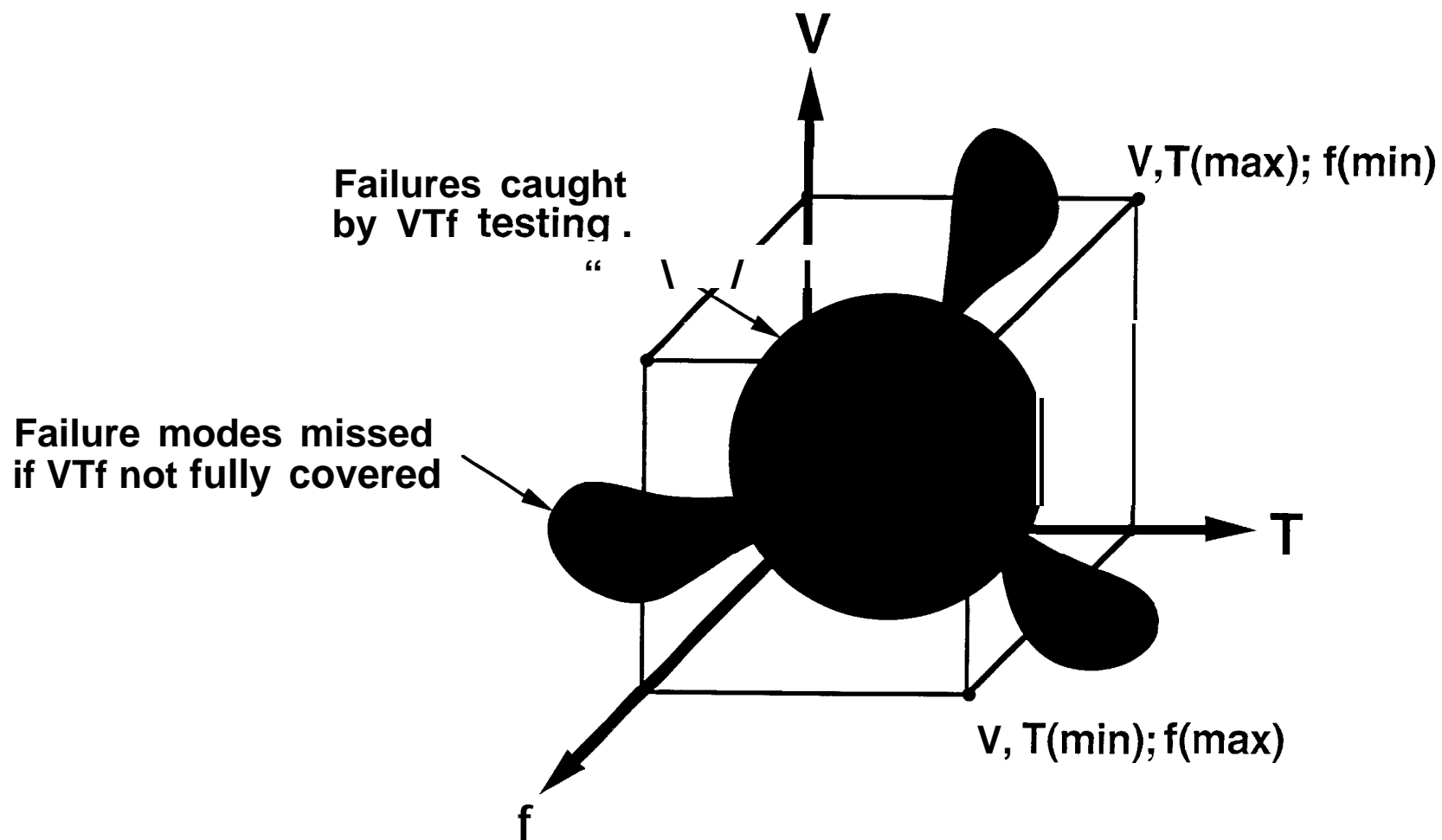
Summary of Objectives

	Objectives - validate performance under the following conditions:						
	Voltage AV	Input signal ΔSi	Temperature AT		Frequency Af	Vacuum Vac	Atmosphere Atm
Tests and Analyses			hot	cold			
WCA	√	√	√	√	√		√
Thermal- vacuum			√	√		√	
VTMT	√	√	√	√	√		√
Vacuum						√	

- VTMT and Vac appears to be “equivalent” to WCA and Thermal/Vat.

Ideal VTfMT Test Conditions

Test at max. and min. of T-V-f parameters for all 8 extreme conditions:



Examples of Major Failure Modes Found at Different Conditions

<u>Temperature</u>		<u>Voltage</u>	<u>frequency</u>	<u>Vacuum</u>	<u>Dwell</u>	<u>Cycle</u>
<u>hot</u>	<u>cold</u>					
<ul style="list-style-type: none"> -Arrhenius (FM accelerated by temp - positive act. energy) -in parts .gate oxide breakdown ionic contamin. .electro-migration -CTE mismatches interconnects solder joints -corrosion -hysteresis -lubrication breakdown 	<ul style="list-style-type: none"> -Arrhenius (FM with positive act. energy) -CTE mismatches interconnects solder joints -hysteresis -fluid viscosity -timing margin -propagation delays -condensation 	<ul style="list-style-type: none"> -open -short -Arrhenius FM -noise -switching -current stress -leakage current -interconnect -dielectric breakdown -turn-on time 	<ul style="list-style-type: none"> -loss of timing (master clock, output) -noise 	<ul style="list-style-type: none"> -outgassing -hermeticity -corona discharge -temp gradient -temp increase -loss of lubrication 	<ul style="list-style-type: none"> -Arrhenius FMs accelerated by temp for long duration -corrosion -life -degradation -workmanship 	<ul style="list-style-type: none"> -CTE mismatch -hysteresis -fatigue stress



OPTIONS

1. VTMT in a vacuum chamber with both hot and cold temperatures.
 - . Best option.
 - . Covers V, input signal, frequency, vat, hot, and cold.
2. VTMT in a vacuum chamber without cold temperature.
 - . Misses cold failure modes.
 - . For some failure modes, cold may be more effective than hot. (e.g. "residual voltage" and "zero crossings" failure modes in 1553 transceivers used in Cassini).
3. VTMT on the bench with only hot and cold temperatures (no vacuum).
 - . Misses vacuum failure modes.
 - . Data from ETEA Report (JPL D-11295, Rev. B) indicate problems /failures found in vacuum could be significant. (45.7% for Voyager and 22.2% for GLL assembly test - conservative numbers).
4. VTMT on the bench with only hot temperature (no vacuum and no cold temperature).
 - . Most economical in terms of cost & schedule.
 - . Misses cold and vacuum failure modes.
 - . Option not recommended for some hardware, e.g. optical equipment.

Relative Effectiveness of Hot and Cold Tests

ENVIRONMENT	<u>2 FAILURE MODES IN 1553 TRANSCEIVERS</u>	
	<u>Residual Voltage</u>	<u>"zero" Crossings</u>
	# of Failures, total =22	# of Failures, total =24
Hot (85 °C) and Cold (-30 °C)	22	24
Room T only	11	0
Room T and Cold	21	17
Room T and Hot	17	7

. Cold can be effective.



Relative Effectiveness of Thermal-Vac Tests*

ENVIRONMENT	<u>Assembly-Level</u>	
	<u>VOYAGER</u>	<u>GALILEO</u>
	# of P/FRs, total =46	# of P/FRs, total =36
T only	9 (16.670)	7 (19.4YO)
T and Vac	10 (21 .7%)	17 (47.2%)
Vac only	21 (45.770)	8 (22.2%)
Undetermined	4 (8.7%)	3 (8.3%)
No T or Vac required	2 (4.3%)	1 (2.8%)

ENVIRONMENT	<u>System-Level</u>	
	<u>VOYAGER</u>	<u>GALILEO</u>
	# of P/FRs, total =46	# of P/FRs, total =39
T only	0 (0%)	4 (1 0.3%)
T and Vac	6 (13Yo)	5 (12.8%)
Vac only	29 (63%)	14 (35.9%)
Undetermined	2 (4.370)	2 (5.170)
No T or Vac required	9 (19.6Yo)	14 (35.9%)

* tables from ETEA Report D-11295, Rev. B

- Vac can be effective.



Common Types of Circuits & Critical Attributes (for illustrations only)

Techniques for Capturing Attributes					
Circuit Type	Attribute	Analysis	Breadboard Test	Unit Test	Remarks
Amplifiers	Gain	WCA	Yes	No	
	Frequency Response	WCA	Yes	Minimal	
	Power Consumption	PSA	NA	NA	
	Noise	WCA	Yes	No	
	Power Sensitivity	WCA	Yes	No	
	Power Output				
	Isolation				
	Input Impedance	WCA	Yes		
	Output Impedance	WCA	Yes		
	Linearity				
Batteries	Outrush Current	No	Yes	Yes	
	Capacity	No	Yes	Yes	
	Trickle Charge	No	Yes	Yes	
	Shorted cells	WCA, FMEA	Yes	Yes	
	Open Cells	WCA, FMEA	No	No	
	Depth of Discharge	No	Yes	Yes	
	Lifetime/Cycles	No	Yes	Yes	
	Impedance	Yes	Yes	Yes	
A-to-D Converters	Timing	Yes	Yes	No	
	Resolution	Yes	Yes	No	
	Slewing		No	No	
	Power Sensitivity	PSA	No	No	
Analog Circuits	Isolation				
	Noise	No	Yes	No	
	Gain	WCA	Yes	No	
	Stability	WCA	Yes	No	
	Filters		Yes	No	
	Input Impedance		Yes	No	
	Linearity	WCA	Yes	No	
Radio Frequency					
D-to-A Converters					
Digital Circuits					
Batteries					